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REPORT

ON

FALL RIVER RESERVOIR

GREENWOOD COUNTY

KANSAS

EPA REGION VII

WORKING PAPER No. 514

WITH THE COOPERATION OF THE

KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

AND THE

KANSAS NATIONAL GUARD

APRIL, 1977

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Kansas State Department of Health and Environment for professional involvement, to the Kansas National Guard for conducting the tributary sampling phase of the Survey, and to those Kansas wastewater treatment plant operators who voluntarily provided effluent samples and flow data.

The staff of the Kansas Division of Environmental Health provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Edward R. Fry, the Adjutant General of Kansas, and Project Officer Colonel Albin L. Lundquist, who directed the volunteer efforts of the Kansas National Guard men, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

STATE OF KANSAS

NAME	COUNTY
Cedar Bluff	Trego
Council Grove	Morris
Elk City	Montgomery
Fall River	Greenwood
John Redmond	Coffey, Lyon
Kanopolis	Ellsworth
Marion	Marion
Melvern	Osage
Milford	Clay, Geary
Norton	Norton
Perry	Jefferson
Pomona	Osage
Toronto	Greenwood, Woodson
Tuttle Creek	Marshall, Pottawatomie, Riley
Wilson	Russell

FALL RIVER RESERVOIR
Eureka

FALL RIVER RESERVOIR

STORET NO. 2004

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate Fall River Reservoir is potentially eutrophic. However, the reservoir becomes quite turbid during periods of runoff, and primary productivity is intermittently light-limited (Kring, 1977).

This water body ranked fifth in overall trophic quality when the 15 Kansas reservoirs sampled in 1974 were compared using a combination of six parameters*. Six of the reservoirs had less median total phosphorus, seven had less median dissolved orthophosphorus, six had less median inorganic nitrogen, four had less mean chlorophyll a, and 12 had greater mean Secchi disc transparency.

Survey limnologists did not observe algal concentrations or aquatic macrophytes but noted the reservoir was quite turbid.

B. Rate-Limiting Nutrient:

The algal assay results indicate Fall River Reservoir was phosphorus limited at the times the samples were taken (04/10/74 and 10/02/74).

The reservoir data also indicate phosphorus limitation at those times. However, the low Secchi disc transparencies, the low

* See Appendix A.

numbers of phytoplankton (page 7), and the relatively low chlorophyll a concentrations indicate productivity was light-limited at least part of the time.

C. Nutrient Controllability:

1. Point sources--The estimated phosphorus contribution of the City of Eureka amounted to 21.3% of the total load reaching Fall River Reservoir during the sampling year.

The present phosphorus loading of 1.84 g/m^2/yr is nearly two times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 24). However, the mean hydraulic retention time of the reservoir is a rather short 40 days, and Vollenweider's model may not be applicable (note the apparent loss of both nitrogen and phosphorus during the sampling year; page 14).

Even complete removal of phosphorus at the Eureka wastewater treatment plant would still leave a phosphorus loading of 1.45 g/m^2/yr; and in view of the intermittently light-limited primary productivity in the reservoir, point-source phosphorus control would not be expected to result in a significant improvement in the trophic condition of Fall River Reservoir.

2. Non-point sources--Nearly 78% of the total phosphorus load to the reservoir during the sampling year came from non-point sources. The Fall River contributed 37.6% of the total; Otter

Creek, 18.6%, and the ungaged tributaries contributed an estimated 21.3%.

The phosphorus export rates of Fall River and Otter Creek were 9 and 11 kg/km^2/yr, respectively (see page 13) and compare well with the rates of three gaged tributaries of nearby Toronto Reservoirs (mean of 12 kg/km^2/yr).

* Working Paper No. 623.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS[1]

A. Morphometry[11]:

1. Surface area: 10.52 kilometers^2.
2. Mean depth: 3.0 meters.
3. Maximum depth: 11.0 meters.
4. Volume: 29.5 x 10^6 m^3.
5. Fourteen-year median hydraulic retention time: 40 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Fall River	795.1	5.41
Otter Creek	334.1	2.40
Minor tributaries & immediate drainage -	375.4	2.46
Totals	1,504.6	10.27

2. Outlet -

Fall River	1,515.1**	9.26

C. Precipitation***:

1. Year of sampling: 114.5 centimeters.
2. Mean annual: 93.5 centimeters.

[1] Table of metric conversions--Appendix B.
[11] Kring, 1977.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Fall River Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at two stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 9.1 meters at station 1 and 3.0 meters at station 2.

The sampling results are presented in full in Appendix D and are summarized in the following table (the June nutrient samples were not properly preserved and were not analyzed).

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/10-11/74	1. Asterionella sp.	211
	2. Cryptomonas sp.	210
	3. Chroomonas sp.	158
	4. Melosira sp.	105
	5. Stephanodiscus sp.	106
	Other genera	106
	Total	896
06/24/74	1. Cryptomonas sp.	1,702
	2. Chroomonas sp.	75
	3. Stephanodiscus sp.	791
	4. Synedra sp.	63
	5. Anabaena sp.	32
	Other genera	32
	Total	2,911
10/02/74	1. Chroomonas sp.	550
	2. Melosira sp.	220
	3. Closterium sp.	44
	4. Nitzschia sp.	22
	5. Stephanodiscus sp.	22
	Other genera	21
	Total	879

B. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
04/10-11/74	1	4.3
	2	4.6
06/24/74	1	18.9
	2	10.8
10/02/74	1	2.5
	2	5.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. April sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	<0.005	0.440	0.4
0.050 P	<0.055	0.440	14.0
0.050 P + 1.0 N	<0.055	1.440	21.8
1.0 N	<0.005	1.440	0.3

b. October sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.025	0.495	5.5
0.050 P	0.075	0.495	14.9
0.050 P + 1.0 N	0.075	1.495	30.1
1.0 N	0.025	1.495	4.8

2. Discussion

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Fall River Reservoir was moderate in April and high in October. In both assay samples, yields increased when only phosphorus was added, but no such response occurred when only nitrogen was added. These results indicate Fall River Reservoir was phosphorus limited at the times the samples were taken.

The reservoir data also indicate phosphorus limitation. The mean inorganic nitrogen to orthophosphorus ratios were 33 to 1 in April and 29 to 1 in October, and phosphorus limitation would be expected. However, the low Secchi disc transparencies, the low numbers of phytoplankton, and the relatively low chlorophyll a concentrations indicate primary productivity in the reservoir was light-limited rather than nutrient-limited at least part of the time.

IV. NUTRIENT LOADINGS
(See Appendix I for data)

For the determination of nutrient loadings, the Kansas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of May and June when two samples were collected at most of the sites. Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Kansas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the nutrient loads at station 8-1, in kg/km^2/year, and multiplying by the ZZ area in km^2.

The operator of the Eureka wastewater treatment plant provided monthly effluent samples but could not provide flow data. Therefore, nutrient loads were estimated at 1.134 P and 3.401 N/capita/year, and flows were estimated at 0.3785 m^3/capita/day.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipals .

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Eureka	1,631	tr. filter	1,374.3	Fall River

2. Known industrial - None

* Treatment plant questionaire.

B. Annual total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Fall River	7,290	37.6
Otter Creek	3,645	18.8
b. Minor tributaries & immediate drainage (non-point load) -	4,130	21.3
c. Known municipal STP's -		
Eureka	4,120	21.3
d. Septic tanks* -	5	<0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	185	1.0
Total	19,375	100.0

2. Outputs -

Reservoir outlet - Fall River 24,695

3. Net annual P loss - 5,320 kg.

* Estimate based on 20 shoreline dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Fall River	244,460	48.2
Otter Creek	110,110	21.9
b. Minor tributaries & immediate drainage (non-point load) -	123,860	24.7
c. Known municipal STP's -		
Eureka	12,360	2.4
d. Septic tanks* -	215	<0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	11,355	2.3
Total	502,370	100.0

2. Outputs -

Reservoir outlet - Fall River	542,230

3. Net annual N loss - 39,860 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Fall River	7	307
Otter Creek	11	330

* Estimate based on 20 shoreline dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	1.84	loss*	47.6	loss*

Vollenweider phosphorus loadings (g/m^2/yr) based on mean depth and 14-year median hydraulic retention time of Fall River Reservoir:

"Dangerous" (eutrophic loading)	1.0
"Permissible" (oligotrophic loading)	0.5

* There was an apparent loss of nutrients during the sampling year. This may have been due to unknown point sources discharging below sampling station A-2 or directly to the reservoir, solubilization of previously sedimented nutrients, recharge with nutrient rich ground water, or (probably) insufficient outlet sampling in relation to the short hydraulic retention time of the reservoir.

V. LITERATURE REVIEWED

Kring, R. Lynn, 1977. Personal communication (revised morphometry; primary productivity in reservoir). KS Dept. of Health & Environment, Topeka.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] DATA A	SEC [illegible] SEC	[illegible] CHLOR	[illegible]	[illegible]
2801	CEDAR BLUFF RESERVOIR	0.017	0.055	431,457	4.237	10,603	0.004
2802	COUNCIL GROVE	0.069	0.038	465,884	5.769	10,488	0.029
2803	ELK CITY	0.031	0.598	490,488	3.232	14,886	0.003
2804	FALL RIVER RESERVOIR	0.053	0.478	488,567	7.683	5,208	0.006
2805	JOHN REDMOND RESERVOIR	0.118	1.258	492,867	9.467	8,208	0.006
2806	KANOPOLIS RESERVOIR	0.056	0.648	487,888	15,888	18,208	0.001
2807	MARION RESERVOIR	0.052	0.438	483,667	12,408	5,208	0.005
2808	MELVERN RESERVOIR	0.034	0.265	488,111	18,488	24,488	0.007
2809	MILFORD RESERVOIR	0.076	0.708	484,333	15,883	12,208	0.006
2810	NORTON RESERVOIR	0.122	0.138	476,758	21,368	8,888	0.016
2811	PERRY RESERVOIR	0.055	0.478	478,571	5.634	13,488	0.007
2812	POMONA RESERVOIR	0.048	1.291	481,333	6.382	13,888	0.001
2813	TORONTO RESERVOIR	0.067	0.425	488,588	6.582	13,888	0.711
2814	TUTTLE CREEK RESERVOIR	0.362	6.578	478,667	11,278	13,488	0.067
2815	WILSON RESERVOIR	0.021	0.265	446,222	6.867	13,488	0.004

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	2001	[illegible]	536
2	2015	[illegible]	436
3	2007	[illegible]	357
4	2003	[illegible]	356
5	2004	[illegible]	329
6	2008	[illegible]	326
7	2013	[illegible]	303
8	2010	[illegible]	282
9	2011	[illegible]	279
10	2006	[illegible]	271
11	2012	[illegible]	267
12	2002	[illegible]	238
13	2009	[illegible]	214
14	2005	[illegible]	164
15	2014	[illegible]	139

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	SUB-MEAN SEC	MEAN CHLORA	15-MIN 10	MEDIAN DISS ORTHO P	INDEX NO
2001	[illegible]	100 (140)	101 (140)	101 (140)	93 (131)	57 (80)	89 (125)	539
2002	[illegible]	29 (40)	29 (40)	36 (50)	43 (60)	64 (90)	29 (40)	236
2003	ELK CITY	86 (120)	57 (79)	7 * 10	100 (140)	7 (10)	106 (149)	350
2004	[illegible]	57 (80)	57 (80)	14 (20)	71 (100)	79 (110)	50 (70)	329
2005	[illegible]	14 (20)	0 (0)	0 (0)	50 (70)	93 (130)	7 (10)	194
2006	[illegible]	43 (60)	43 (60)	29 (40)	21 (30)	71 (100)	64 (90)	271
2007	[illegible]	64 (90)	64 (90)	43 (60)	29 (40)	86 (120)	71 (100)	357
2008	[illegible]	79 (110)	62 (110)	64 (120)	7 (10)	0 (0)	79 (110)	321
2009	[illegible]	21 (30)	36 (50)	79 (110)	14 (20)	50 (70)	14 (20)	214
2010	[illegible]	7 (10)	93 (130)	64 (90)	7 (10)	100 (140)	21 (30)	292
2011	[illegible]	50 (70)	29 (20)	57 (80)	64 (120)	25 (30)	43 (60)	279
2012	[illegible]	71 (100)	7 (10)	51 (70)	64 (90)	29 (50)	34 (50)	297
2013	[illegible]	36 (50)	71 (100)	21 (30)	79 (110)	36 (50)	57 (80)	302
2014	[illegible]	0 (0)	14 (20)	71 (100)	36 (50)	14 (20)	0 (0)	129
2015	[illegible]	93 (130)	62 (110)	93 (130)	57 (80)	25 (30)	64 (120)	436

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

[illegible]

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

[illegible]

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